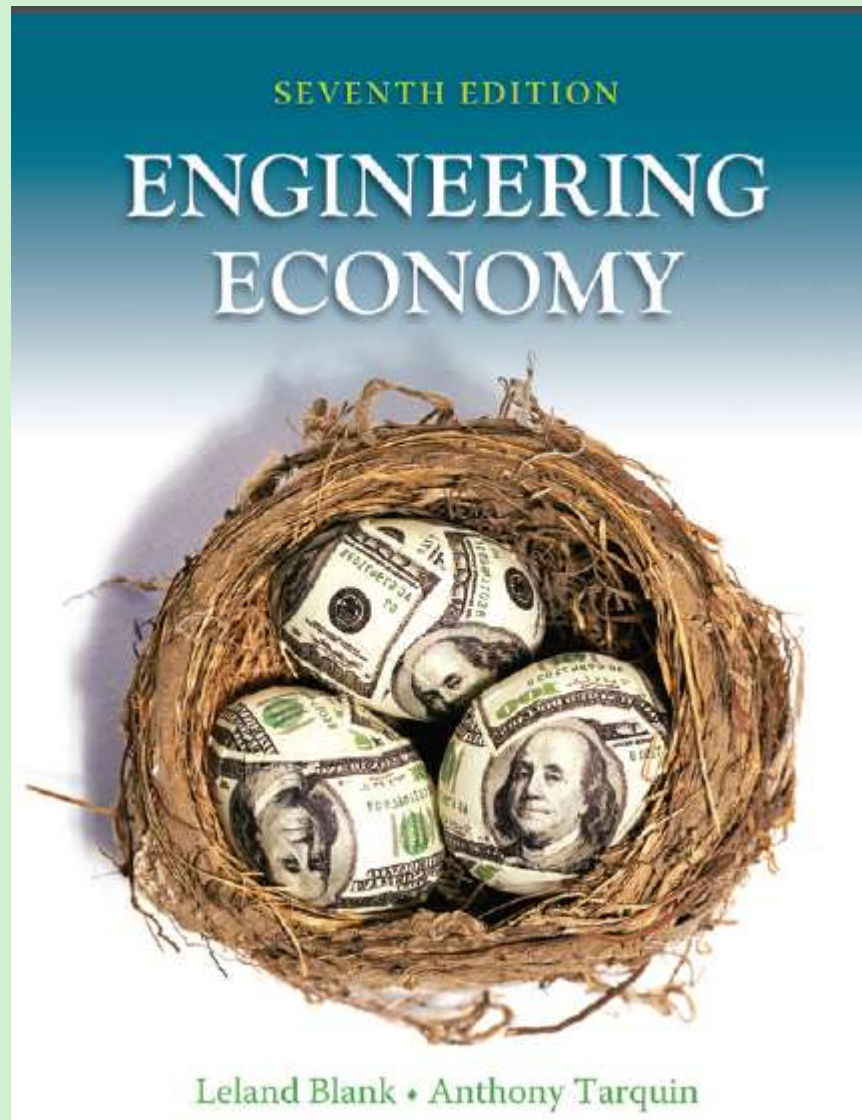




Chapter 9

Benefit/Cost Analysis

Lecture slides to accompany

Engineering Economy

7th edition

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LEARNING OUTCOMES

- 1. Explain difference in public vs. private sector projects**
- 2. Calculate B/C ratio for single project**
- 3. Select better of two alternatives using B/C method**
- 4. Select best of multiple alternatives using B/C method**
- 5. Use cost-effectiveness analysis (CEA) to evaluate service sector projects**
- 6. Describe how ethical compromises may enter public sector projects**

Differences: Public vs. Private Projects

Characteristic

Public

Private

Size of Investment

Large

Small, medium, large

Life

Longer (30 – 50+ years)

Shorter (2 – 25 years)

Annual CF

No profit

Profit-driven

Funding

Taxes, fees, bonds, etc.

Stocks, bonds, loans, etc.

Interest rate

Lower

Higher

Selection criteria

Multiple criteria

Primarily ROR

Environment of evaluation

Politically inclined

Economic

Types of Contracts

Contractors **does not share** project risk

- **Fixed price** - lump-sum payment
- **Cost reimbursable** - Cost plus, as negotiated

Contractor **shares** in project risk

- **Public-private partnerships (PPP)**, such as:
 - **Design-build projects** - Contractor responsible from design stage to operations stage
 - **Design-build-operate-maintain-finance (DBOMF) projects** - Turnkey project with contractor managing **financing** (manage cash flow); government obtains **funding** for project

Cash Flow Classifications and B/C Relations

Must identify each cash flow as either benefit, disbenefit, or cost

Benefit (B) -- Advantages to the public

Disbenefit (D) -- Disadvantages to the public

Cost (C) -- Expenditures by the government

Note: Savings to government are subtracted from costs

Conventional B/C ratio = $(B - D) / C$

Modified B/C ratio = $[(B - D) - M\&O] / \text{Initial Investment}$

Profitability Index = $NCF / \text{Initial Investment}$

Note 1: All terms must be expressed in *same units*, i.e., PW, AW, or FW

Note 2: Do not use minus sign ahead of costs

Decision Guidelines for B/C and PI

Benefit/cost analysis

If $B/C \geq 1.0$, project **is** economically justified at discount rate applied

If $B/C < 1.0$, project **is not** economically acceptable

Profitability index analysis of revenue projects

If $PI \geq 1.0$, project **is** economically justified at discount rate applied

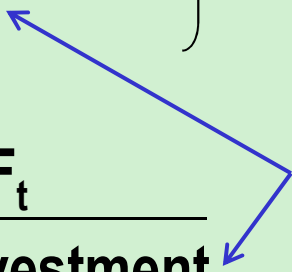
If $PI < 1.0$, project **is not** economically acceptable

B/C Analysis – Single Project

Conventional B/C ratio = $\frac{B - D}{C}$

Modified B/C ratio = $\frac{B - D - M\&O}{C}$

If $B/C \geq 1.0$,
accept project;
otherwise, reject



$PI = \frac{PW \text{ of } NCF_t}{PW \text{ of initial investment}}$

Denominator is
initial investment

If $PI \geq 1.0$,
accept project;
otherwise, reject

Example: B/C Analysis – Single Project

A flood control project will have a first cost of \$1.4 million with an annual maintenance cost of \$40,000 and a 10 year life. Reduced flood damage is expected to amount to \$175,000 per year. Lost income to farmers is estimated to be \$25,000 per year. At an interest rate of 6% per year, should the project be undertaken?

Solution: Express all values in AW terms and find B/C ratio

$$B = \$175,000$$

$$D = \$25,000$$

$$C = 1,400,000(A/P, 6\%, 10) + \$40,000 = \$230,218$$

$$\begin{aligned} B/C &= (175,000 - 25,000)/230,218 \\ &= 0.65 < 1.0 \end{aligned}$$

Do not build project

Defender, Challenger and Do Nothing Alternatives

When selecting from two or more ME alternatives, there is a:

- ✓ **Defender** – in-place system or currently selected alternative
- ✓ **Challenger** – Alternative challenging the defender
- ✓ **Do-nothing option** – Status quo system

General approach for incremental B/C analysis of two ME alternatives:

- Lower total cost alternative is first compared to **Do-nothing (DN)**
- If B/C for the lower cost alternative is < 1.0 , the DN option is compared to $\Delta B/C$ of the higher-cost alternative
- If both alternatives lose out to DN option, DN prevails, unless overriding needs requires selection of one of the alternatives

Alternative Selection Using Incremental B/C Analysis – Two or More ME Alternatives

Procedure similar to ROR analysis for multiple alternatives

- (1) Determine *equivalent total cost* for each alternative
- (2) Order alternatives *by increasing total cost*
- (3) Identify *B and D for each alternative*, if given, or go to step 5
- (4) Calculate B/C for each alternative and *eliminate all with $B/C < 1.0$*
- (5) Determine *incremental costs and benefits* for first two alternatives
- (6) Calculate $\Delta B/C$; if > 1.0 , *higher cost alternative becomes defender*
- (7) Repeat steps 5 and 6 *until only one alternative remains*

If $\Delta B/C \geq 1.0$, choose the higher-cost alternative, because its extra cost is economically justified.

If $\Delta B/C < 1.0$, choose the lower-cost alternative.

Example: Incremental B/C Analysis

Compare two alternatives using $i = 10\%$ and B/C ratio

Alternative	X	Y
First cost, \$	320,000	540,000
M&O costs, \$/year	45,000	35,000
Benefits, \$/year	110,000	150,000
Disbenefits, \$/year	20,000	45,000
Life, years	10	20

Solution: First, calculate equivalent total cost

$$AW \text{ of costs}_X = 320,000(A/P, 10\%, 10) + 45,000 = \$97,080$$

$$AW \text{ of costs}_Y = 540,000(A/P, 10\%, 20) + 35,000 = \$98,428$$

Order of analysis is X, then Y

X vs. DN: $(B-D)/C = (110,000 - 20,000) / 97,080 = 0.93$ **Eliminate X**

Y vs. DN: $(150,000 - 45,000) / 98,428 = 1.07$ **Eliminate DN**

Select Y

Example: $\Delta B/C$ Analysis; Selection Required

Must select one of two alternatives using $i = 10\%$ and $\Delta B/C$ ratio

Alternative	X	Y
First cost, \$	320,000	540,000
M&O costs, \$/year	45,000	35,000
Benefits, \$/year	110,000	150,000
Disbenefits, \$/year	20,000	45,000
Life, years	10	20

Solution: Must select X or Y; DN not an option, compare Y to X

AW of costs_x = \$97,080

AW of costs_y = \$98,428

Incremental values: $\Delta B = 150,000 - 110,000 = \$40,000$

$\Delta D = 45,000 - 20,000 = \$25,000$

$\Delta C = 98,428 - 97,080 = \$1,348$

Y vs. X: $(\Delta B - \Delta D) / \Delta C = (40,000 - 25,000) / 1,348 = 11.1$ **Eliminate X**

Select Y

B/C Analysis of Independent Projects

- ❖ Independent projects comparison does **not require incremental analysis**
 - ❖ Compare each alternative's overall B/C with **DN option**
-

- + **No budget limit:** **Accept all** alternatives with **$B/C \geq 1.0$**
- + **Budget limit specified:** capital budgeting problem; selection follows different procedure (discussed in chapter 12)

Cost Effectiveness Analysis

Service sector projects primarily involve **intangibles**, **not physical facilities**; examples include health care, security programs, credit card services, etc.

Cost-effectiveness analysis (CEA) combines monetary cost estimates with **non-monetary** benefit estimates to calculate the

Cost-effectiveness ratio (CER)

$$\begin{aligned}\text{CER} &= \frac{\text{Equivalent total costs}}{\text{Total effectiveness measure}} \\ &= \text{C/E}\end{aligned}$$

CER Analysis for Independent Projects

Procedure is as follows:

- (1) Determine equivalent total cost **C**, total effectiveness measure **E** and **CER**
- (2) Order projects by smallest to largest CER
- (3) Determine cumulative cost of projects and compare to budget limit **b**
- (4) Fund all projects such that **b is not exceeded**

Example: The effectiveness measure **E** is the number of graduates from adult training programs. For the CERs shown, determine which *independent* programs should be selected; $b = \$500,000$.

<u>Program</u>	<u>CER, \$/graduate</u>	<u>Program Cost, \$</u>
A	1203	305,000
B	752	98,000
C	2010	126,000
D	1830	365,000

Example: CER for Independent Projects

First, rank programs according to increasing CER:

Program	CER, \$/graduate	Program Cost, \$	Cumulative Cost, \$
B	752	98,000	98,000
A	1203	305,000	403,000
D	1830	365,000	768,000
C	2010	126,000	894,000

Next, select programs until budget is not exceeded

✦ **Select programs B and A at total cost of \$403,000** ✦

Note: To expend the entire \$500,000, accept as many additional individuals as possible from D at the per-student rate

CER Analysis for Mutually Exclusive Projects

Procedure is as follows

- (1) Order alternatives smallest to largest by effectiveness measure E
- (2) Calculate **CER for first alternative** (defender) and compare to DN option
- (3) Calculate incremental cost (ΔC), effectiveness (ΔE), and incremental measure **$\Delta C/E$ for challenger** (next higher E measure)
- (4) If $\Delta C/E_{\text{challenger}} < C/E_{\text{defender}}$ challenger becomes defender (**dominance**); otherwise, **no dominance** is present and both alternatives are retained
- (5) **Dominance present:** Eliminate defender and compare next alternative to new defender per steps (3) and (4).
Dominance not present: Current challenger becomes new defender against next challenger, **but old defender remains viable**
- (6) Continue steps (3) through (5) until only **1 alternative remains** or only **non-dominated alternatives remain**
- (7) Apply budget limit or other criteria to **determine which of remaining non-dominated alternatives** can be funded

Example 1: CER for ME Service Projects

The effectiveness measure **E is wins per person**. From the cost and effectiveness values shown, determine which alternative to select.

<u>Program</u>	<u>Cost (C)</u> <u>\$/person</u>	<u>Effectiveness (E)</u> <u>wins/person</u>	<u>CER</u> <u>\$/win</u>
A	2200	4	550
B	1400	2	700
C	6860	7	980

Example 1: CER for ME Service Projects

Solution:

Order programs according to increasing effectiveness measure *E*

Program	Cost (C) \$/person	Effectiveness (E) wins/person	CER \$/win
B	1,400	2	700
A	2,200	4	550
C	6,860	7	980

B vs. DN: $C/E_B = 1400/2 = 700$

A vs. B: $\Delta C/E = (2200 - 1400)/(4 - 2) = 400$ Dominance; eliminate B

C vs. A: $\Delta C/E = (6860 - 2200)/(7 - 4) = 1553$ No dominance; retain C

Must use other criteria to select either A or C

Example 2: CER for ME Service Projects

TABLE 9-4 Mutually Exclusive Alternatives Evaluated by Cost-Effectiveness Analysis, Example 9.9

Program (1)	Total Personnel (2)	Cost/Person C, \$ (3)	Patents per Year E (4)	CER, \$ per Patent (5) = (3)/(4)	Program Cost, \$ (6) = (2)(3)
4	50	2,500	2.1	1190	125,000
5	50	5,500	2.9	1897	275,000
2	50	4,500	3.1	1452	225,000

5. *Dominance not present:* Program 5 becomes the new defender, and program 2 is the new challenger. Perform the 2-to-5 comparison.

column 4.

$$\text{2-to-5 comparison: } \Delta C/E = \frac{\Delta C}{\Delta E} = \frac{4500 - 5500}{3.1 - 2.9} = -5000$$

Compared to $C/E_5 = 1897$, this increment is much cheaper—more patents for less money per person. Dominance is present; eliminate program 5 and compare 2 to 4.

6. Repeat steps 3 through 5 and compare $\Delta C/E$ to $C/E_4 = 1190$.

$$\text{2-to-4 comparison: } \Delta C/E = \frac{\Delta C}{\Delta E} = \frac{4500 - 2500}{3.1 - 2.1} = 2000$$

This does not represent dominance of program 2 over 4. The conclusion is that both programs are eligible for funding, that is, CEA in this case does not indicate only one program. This occurs when there is not lower cost and higher effectiveness of one alternative over another; that is, one alternative does not dominate all the others.

Program 5 is chosen
dominance is not

7. Now the budget and other considerations (probably noneconomic) are brought to bear to make the final decision. The fact that program 4 costs \$125,000—significantly less than program 2 at \$225,000—will likely enter into the decision.

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Ethical Considerations

Engineers are routinely involved in two areas where ethics may be compromised:

Public policy making – **Development of strategy**, e.g., water system management (supply/demand strategy; ground vs. surface sources)

Public planning - **Development of projects**, e.g., water operations (distribution, rates, sales to outlying areas)

**Engineers must maintain integrity and impartiality and
always adhere to Code of Ethics**

Summary of Important Points

- ✦ B/C method used in *public sector* project evaluation
- ✦ Can use PW, AW, or FW for incremental B/C analysis, but must *be consistent* with units for B, C, and D estimates
- ✦ For multiple mutually exclusive alternatives, compare two at a time and eliminate alternatives until *only one remains*
- ✦ For independent alternatives with no budget limit, compare each against **DN** and select *all alternatives that have $B/C \geq 1.0$*
- ✦ **CEA analysis** for service sector projects combines cost and *nonmonetary measures*
- ✦ Ethical dilemmas are *especially prevalent* in public sector projects